Original Article

Point-of-care ultrasound in the airway assessment: A correlation of ultrasonography-guided parameters to the Cormack-Lehane Classification

ABSTRACT

Background and Aim: The sonographic assessment of airway in the preoperative period has encouraging results in predicting difficult laryngoscopy.

Materials and Methods: The prospective, observational study was conducted on 120 patients scheduled for elective surgery requiring general anesthesia and tracheal intubation. The depth of the pre-epiglottic space (Pre-E), the distance from the epiglottis to the midpoint of the distance between the vocal cords (E-VC) was measured sonographically. Similarly, hyomental distance ratio (HMDR) was sonographically measured with head in neutral and extended positions. The primary outcome was the efficacy of Pre E/E-VC, HMDR for predicting difficult laryngoscopy (Cormack–Lehane [CL] Grade 3, 4). The secondary outcome was to correlate these parameters to CL grading.

Results: Difficult intubation was observed in 12.5% of patients. The mean ± standard deviation (SD) of Pre E/E-VC ratio was 1.33±0.335, 1.62±0.264 and 1.87±.243, 2.22±.29 for CL Grade 1, 2, 3, and 4, respectively (P = 0.00). The mean ± SD of HMDR was 1.11±.35, 1.12±.29, and 1.07±.39, 1.04 ± 0.01 for CL Grade 1, 2, 3, and 4, respectively (P = 0.00). Pre E/E-VC ratio of more than 1.77 cm had 82% sensitivity, specificity 80%, whereas HMDR less than1.085 had sensitivity 75% and specificity 85.3%, in predicting difficult laryngoscopy (P = 0.00).

Conclusion: The sonographic measurement of the Pre E/E-VC ratio is a better predictor of CL grading as compared to HMDR. The noninvasive prediction of CL grading can be precisely done by Pre-E/E-VC ratio (range: 0–1.425 corresponds to CL Grade 1; 1.425–1.77 ≈ CL Grade 2; 1.77–1.865 ≈ CL Grade 3, more than 1.865 corresponds to CL Grade 4).

Key words: Anesthesia general; intubation endotracheal; sonography

Introduction

Airway-related morbidity, as the result of an inability to anticipate difficult airway, remains the primary concern for anesthesiologist.[1] The incidence of difficult laryngoscopy and tracheal intubation still ranges between 1.5%–13%. The inability to predict difficult airways is probably due to high inter-observer variability and low predictability of commonly used airway assessment screening tests.[2,3]

In the study by Takenaka *et al*.,[4] the ratio of hyomental distance in the neutral and head extended positions as

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the hyomental distance ratio (HMDR), correlates well with occipitoatlantoaxial complex extension capacity. Wojtczak[5] concluded that sonographic HMDR in the difficult intubation group were in the range of 1–1.05, whereas the easy group had a range of 1.12–1.16. In recent studies,[6,7] ultrasound (US) measurement of depth of the pre-epiglottic space (Pre-E)/distance from the epiglottis to the midpoint of the distance between the vocal cords (E-VC) done in the preoperative period has been shown to correlate with the Cormack–Lehane (CL) grading.

Therefore, this study was planned to determine the efficacy of US measurement of HMDR and Pre E/E-VC in predicting difficult airway and to observe the correlation with CL grading.

Materials and Methods

After approval by the institutional ethics committee and obtaining informed consent, prospective and observational study was carried out on the American Society of Anesthesiologists I/II patients in the age group of 20–60 years of either gender, scheduled for elective surgery and requiring general anesthesia with direct laryngoscopy and endotracheal intubation. The patients with interincisor gap <3 cm, edentulous patients, and patients with head and neck anatomical pathologies that might have an unpredictable effect on the US assessment of the airway were excluded from the study. Patients having altered level of consciousness, inability to follow commands were also excluded from the study.

The routine airway assessment including mouth opening, modified Mallampati scoring, thyromental distance, and neck movements, was done during the preanesthetic assessment. The patients not meeting inclusion criteria were excluded from the study and the enrolled patients underwent sonographic assessment of airway by the anesthesiologist in the preoperative holding area.

In the preoperative holding area, with the patients lying supine and active maximal head-tilt/chin lift, the sonographic assessment was done. The high-frequency linear probe (SonoSite® MicroMaxx® US system, SonoSite INC, Bothell, WA) was placed in the submandibular area in the midline. Without changing the position of the probe, the linear array of the US probe was rotated in the transverse planes from cephalad to caudal, until simultaneous visualization of the epiglottis and posterior part of vocal folds with arytenoids observed on the screen. Thereafter, following measurements were obtained with the oblique-transverse US view of the airway (a) E-VC, (b) Pre E as described by Gupta *et al*.[3]

Similarly, curved low-frequency (5 MHz) transducer was used to visualize the tongue and shadows of the hyoid bone and mandible with the patient in the supine position. The hyomental distances were measured from the upper border of the hyoid bone to the lower border of the mentum in the neutral and extended head positions, respectively.

The patients were then taken to the operating room and the standard general anesthesia procedure was performed as per the discretion of the attending anesthesiologist and as per standard of care. The patients were induced and intubated by a senior anesthesiologist with >10 years of experience postqualification and was blinded to the findings of preoperative ultrasonographic airway assessment. Direct laryngoscopy was performed using a Macintosh blade, and the CL grade noted without external laryngeal manipulation. The CL classification:[8] Grade 1: visualization of the entire laryngeal aperture; Grade 2: visualization of parts of the laryngeal aperture or the arytenoids; Grade 3: visualization of only the epiglottis; Grade 4: visualization of only the soft palate. The laryngoscopy was classified as easy (CL Grade 1 and 2) or difficult (CL Grade 3 and 4).

The trachea was intubated with appropriate sized endotracheal tube and anesthesia was maintained. The number of attempts at intubation, need for alternative difficult intubation approaches or inability to secure the airway was also noted.

The MS Excel® and SPSS® 19 (SPSS Inc., Chicago, IL, USA) software packages were used for data entry and analysis. The results were averaged (mean ± standard deviation [SD]) for each parameter for continuous data. The Chi-square test was used to determine the statistical difference between the easy and difficult laryngoscopies. The predictive value of the tests was assessed by calculating the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV). To assess the optimal cut-off scores, receiver operating characteristic (ROC) graphs were plotted and the area under the curve was calculated to assess the prognostic accuracy.

Results

One hundred and twenty adult patients undergoing elective surgery under general anaesthesia with endotracheal intubation were included in the study. The demographic profile age, gender, and basal metabolic index were comparable in the easy and difficult laryngoscopy group [Table 1].

It was observed that 40 patients (33%) had CL Grade 1, 65 patients had CL Grade 2 (54%), 10 patients had CL Grade 3 (8.1%), 5 patients belonged to CL grade 4 (4.1%). Therefore, the incidence of easy laryngoscopy was 87.5% and difficult 12.5% [Figure 1]. In the study, 5 patients belonging to CL 4 required either more than a single attempt or additional equipment to achieve endotracheal intubation.

The distribution of CL grade as predicted by ultrasonography measured HMDR was (mean ± SD: 1.11 ± 0.35, 1.12 ± 0.29) for CL Grades 1 and 2, respectively, and HMDR 1.07 ± 0.39 and 1.04 ± 0.01 for CL Grade 3 and 4 ($P = 0.00$). The significant difference was observed amongst all grades ($P = 0.00$) except CL 1 and 2 ($P = 0.908$). The values of Pre E/E-VC ratio were (mean ± SD: 1.33 ± 0.335 and 1.62 ± 0.264) for CL Grade 1, 2, respectively and 1.87 ± 0.243, 2.22 ± 0.29 corresponded to CL Grade 3 and 4 ($P = 0.00$) [Figure 2].

The HMDR had a strong negative correlation with CL grading with an area under the curve (AUC) of 0.871 and regression coefficient of − 0.466 (95% CI : -0.956 to -0.786; $P = 0.00$). Utilizing receiver operating curves and Youden's index, the cutoff value of HMDR for predicting difficult laryngoscopy came out to be ≤1.0850 with sensitivity of 75% and specificity of 85.3%. The NPV of HMDR was 90.1% and PPV 65.6% [Table 2].

Table 1: Demographic profile of the patients in relation to the Cormack–Lehane Grading

Variables	CL grading				*P*
	Easy intubation		Difficult intubation		
	Grade 1	Grade 2	Grade 3	Grade 4	
Age (years)*	43.9±12.0	42.12±15.3	46.59±9.4	45.18±7.12	0.26
Gender (*n*)†					
Male/female: 53/67	13/20	24/35	10/7	6/5	0.43
BMI (kg/m²)*	22.5±12.6	21.9±23.2	21.6±20.4	22.6±11.7	0.12

The data presented as *Mean±SD and †Number as appropriate. BMI: Body mass index; CL: Cormack–Lehane; SD: Standard deviation

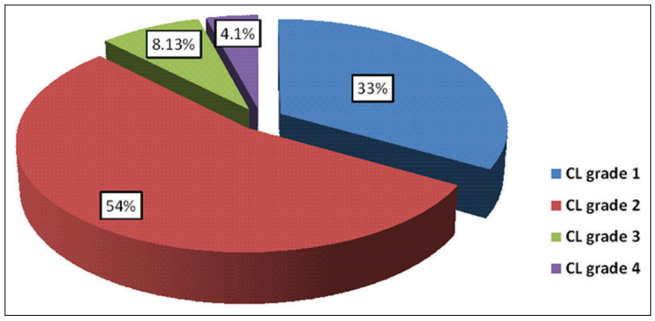


Figure 1: Graphical presentation of distribution of patients in easy and difficult laryngoscopy groups. Easy laryngoscopy corresponded to Cormack–Lehane Grade 1, 2; difficult laryngoscopy: Cormack–Lehane Grade 3, 4. The data presented as percentage

Whereas, Pre E/E-VC had a strong positive correlation with AUC of 0.868 and correlation coefficient of + 0.648 (95% CI: 0.798 to 0.938; $P = 0.00$). The cutoff value of Pre E/E-VC for predicting difficult laryngoscopy was 1.77 with sensitivity of 82% and specificity of 80%. The NPV of Pre E/E-VC was 92.3% and PPV 60.5% [Table 2].

Furthermore, based on the assessment of the ROC curves, the prediction of CL grades can be made by the HMDR range : more than 1.085 corresponds to CL 1 or 2, whereas 0-1.0665 corresponds to CL 4 and 1.0665-1.085 corresponds to CL 3) [Figure 3]. The noninvasive prediction of CL grading can be precisely done by Pre-E/E-VC ratio (range: 0–1.425 corresponds to CL Grade 1; 1.425–1.77 ≈ CL Grade 2; 1.77–1.865 ≈ CL Grade 3, more than 1.865 corresponds to CL Grade 4) [Figure 4].

Discussion

The currently available noninvasive screening tests for airway assessment during pre anesthetic examination are mouth opening, modified Mallampati classification, thyromental distance assessment, atlanto-occipital extension, jaw protrusion, and the upper lip bite test. However, these screening tests alone or in combination not necessarily correlate with the CL grading during direct laryngoscopy, due to low predictive value.[9]

Therefore, noninvasive screening test to predict the difficult laryngoscopy and intubation with greater accuracy in the preoperative period is the need of the hour. Encoraging results have been obtained in few studies,[3,5] utilizing the US directed predictors for the assessment of airway in the preoperative period.

Visualization of the glottis as assessed by CL grading during laryngoscopy depends on several factors, including the

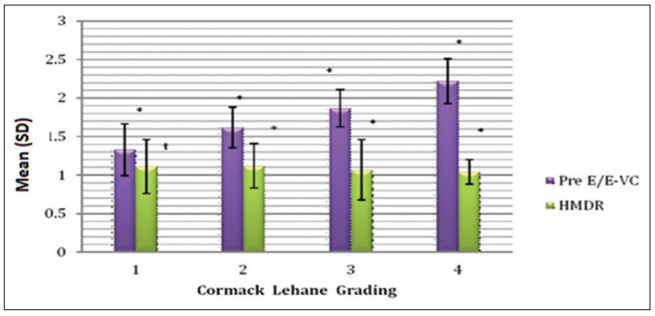
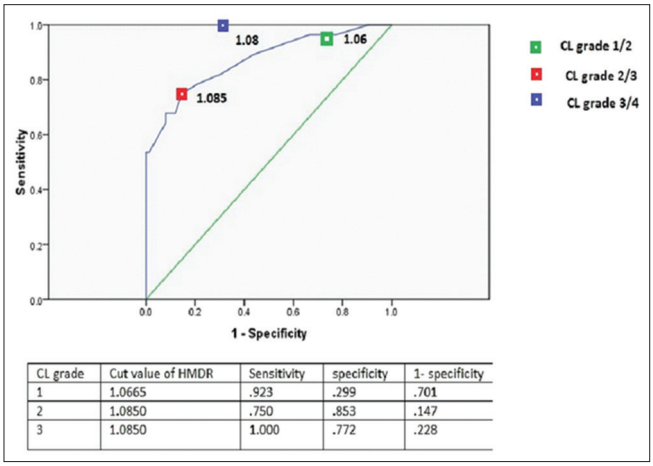


Figure 2: Graphical representation of sonographic predicted HMDR, Pre E/E-VC (mean ± SD) to Cormack–Lehane Grading. HMDR: Hyomental distance ratio. Pre E/E-VC: Ratio of depth of preepiglottic space to the distance between epiglottis and midpoint of vocal cord, *$P = 0.00$; †$P > 0.05$ (HMDR between Cormack–Lehane 1 and Cormack–Lehane 2)

Table 2: Predictive value of ultrasonography measured hyomental distance ratio and ratio of preepiglottic space and distance between midpoint of epiglottis and vocal cord

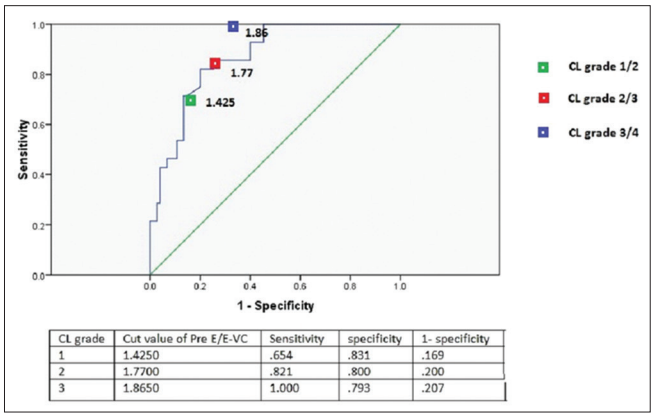
Variables	Easy intubation (CL 1, 2)		Difficult intubation (CL 3, 4)		*P*
	Specificity (%)	Negative predictive value (%)	Sensitivity (%)	Positive predictive value (%)	
Pre-E/E-VC ratio	80	92.3	82.1	60.5	0.000
		Measurement of agreement kappa: 0.559			0.000
HMDR	85.3	90.1	75.0	65.6	0.000
		Measurement of agreement kappa: 0.577			0.000

Pre-E/E-VC: Midpoint of epiglottis and vocal cord; HMDR: Hyomental distance ratio; CL: Cormack–Lehane



CL grade	Cut value of HMDR	Sensitivity	specificity	1- specificity
1	1.0665	.923	.299	.701
2	1.0850	.750	.853	.147
3	1.0850	1.000	.772	.228

Figure 3: Correlation of ultrasonography measured hyomental distance ratio to Cormack–Lehane Grades utilizing receiver operating characteristic graphs (*P* = 0.00)



CL grade	Cut value of Pre E/E-VC	Sensitivity	specificity	1- specificity
1	1.4250	.654	.831	.169
2	1.7700	.821	.800	.200
3	1.8650	1.000	.793	.207

Figure 4: Graphical presentation depicting correlation of Pre E/E-VC and Cormack–Lehane Grades utilizing receiver operating characteristic graphs (*P* = 0.00). Pre E/E-VC: Ratio of depth of preepiglottic space to the distance between epiglottis and midpoint of vocal cord

extension of the head at the occipitoatlantal and atlanto axial joints. Huh *et al*.[10] evaluated the predictive value of surface HMDR measurements in 213 consecutive nonobese adult patients undergoing elective surgery and anesthesia with tracheal intubation. The HMDR alone had the highest predictive validity for difficult laryngoscopy with an optimal cutoff point of 1.2. At this cutoff point, the HMDR had sensitivity of 88% and specificity of 60% for predicting difficult laryngoscopy.

The US guided HMDR has been observed to be a good predictor of CL grading in the study by Wojtczak.[5] Five obese and seven morbidly obese adult patients with a history of either difficult or easy intubation had a submandibular sonographic examination performed in the supine position. The mean HMDR in 6 patients who presented with a history of difficult intubation was 1.02 ± 0.01, and the ratio in 6 patients whose airway was easy to intubate was 1.14 ± 0.02 (P = 0.002). The authors observed that the sonographic HMDRs in the difficult intubation group were in the range of 1–1.05, and those in the easy intubation group were in the 1.12–1.16 range.

In the present study, the range of HMDR is 1.085–1.21 and 1.02–1.15 in the easy and difficult laryngoscopy, respectively (P = 0.00). The difference in the range could be attributed to difference in the profile of the patients, as only 12 obese patients were recruited,[5] in comparison to the present study having 120 patients with basal metabolic index <25 kg/m^2. Second, in the present study, the ROC graphs were utilized to obtain cutoff value of HMDR, as compared to study by Wojtczak.

Regarding the utilization of sonographic guided Pre E/E-VC ratio to CL classification, the values of Pre E/E-VC ratio are (mean ± SD: 1.33 ± 0.335 and 1.62 ± 0.264) for CL Grade 1, 2, respectively, and 1.87 ± 0.243, 2.22 ± 0.29 corresponded to CL Grade 3 and 4 (P = 0.00). In the study by Reddy *et al*., the value of mean Pre E/E-VC were 1.09 ± 0.38, 1.28 ± 0.37 for CL Grade 1 and 2, whereas for CL Grade 3, it was 1.29 ± 0.44. However, in the study, the authors did not encounter patient with CL 4.

The cutoff point for Pre E/E-VC in our study was 1.77 for predicting easy or difficult laryngoscopy in our study, whereas in the study by Gupta *et al*.,[3] the cutoff value was 1.49, with no patient having CL 4.

The non invasive prediction of CL grading can be precisely done by Pre-E/E-VC ratio (range: 0–1.425 corresponds to CL Grade 1; 1.425–1.77 ≈ CL Grade 2; 1.77–1.865 ≈ CL Grade 3,

>1.865 corresponds to CL Grade 4) in the present study. Whereas in the study by Gupta *et al*.,[3] the predictability of the grade was Pre-E/E-VC ratio 0–1 corresponded to CL Grade 1; 1–2 ≈ CL Grade 2, and the ratio between 2 and 3 corresponded to CL Grade 3. The difference may be contributed to difference in the study population involved and nonavailability of patients having CL 4 in the study by Gupta *et al*.[3]

US measurement of HMDR has moderate predictive value in predicting easy and difficult laryngoscopy. However, it was not helpful in predicting CL grade 1 or 2, as the cutoff value was more than 1.085 for both gradings. Whereas the sonography measured Pre E/E-VC ratio is a good predictor for assessing easy and difficult laryngoscopy in the preoperative assessment and correlates well with the CL grading during laryngoscopy. Therefore, these US guided parameters can be used as a valuable noninvasive adjuvant in predicting CL grading in combination with clinical predictors, in the preoperative period.

There are few limitations of this study. We did not have any patient with BMI >30 kg/m^2. Further studies can be done involving patient groups having factors associated with difficult intubation such as pregnancy, obesity. Second, the inter-subject variability can be a limiting factor, particularly in relation with US guided HMDR. Third, the difficult laryngoscopy does not necessarily correlates with difficult intubation, as external laryngeal manipulation tends to facilitate intubation most of the times.

Therefore, we conclude that US measurement of Pre E/E-VC has high predictability with cutoff value >1.77 for predicting difficult laryngoscopy. US measurement of the HMDR is a potential predictor of difficult laryngoscopy. A value <1.085 is sensitive indicator in predicting a difficult laryngoscopy. The noninvasive prediction of CL grading can be precisely done by Pre-E/E-VC ratio (range: 0–1.425 corresponds to CL Grade 1; 1.425–1.77 ≈ CL Grade 2; 1.77–1.865 ≈ CL Grade 3, and more than 1.865 corresponds to CL Grade 4).

There is a need for further evaluating the optimal combination of US guided screening tests including HMDR, Pre E/E-VC and other US-guided predictors like anterior soft tissue neck thickness at the level of hyoid and vocal cord, as diagnostic predictors for the assessment of difficult intubations, in the preoperative period.

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Conflicts of interest
There are no conflicts of interest.

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